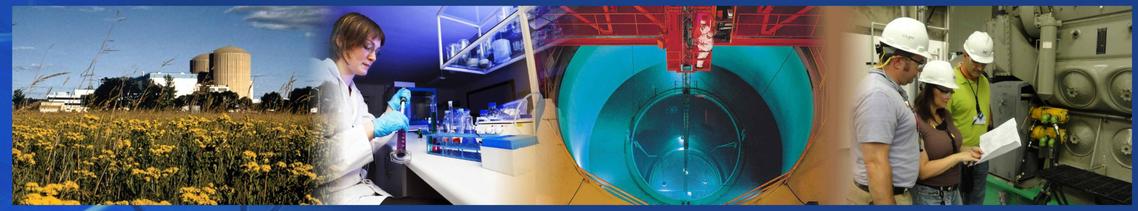
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

RIC 2015



Extremely Low Probability of Rupture (xLPR) Version 2.0

Introduction

- Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria [GDC] for Nuclear Power Plants," GDC 4, requires that primary piping systems exhibit an extremely low probability of rupture to exclude dynamic effects associated with postulated pipe ruptures from the design basis.
- The NRC developed the deterministic leak-before-break (LBB) methodology, as described in its Standard Review Plan (SRP) 3.6.3, to meet this goal.
- The NRC has initiated the development of a probabilistic assessment tool (xLPR) as an alternative to the deterministic evaluation criteria of the SRP.
- This poster provides an overview of the xLPR Version 2.0 code, focusing on the code structure, uncertainty, handling and sample results

Motivation

- Systems approved for LBB have experienced degradation mechanisms such as stress corrosion cracking. The SRP was developed before the advent of this operating experience. The xLPR will provide a probabilistic framework to address degradation mechanisms.
- In addition to modeling degradation mechanisms, xLPR models mitigation strategies (such as weld overlays) and the influence of inspection technology on pipe failure frequency.

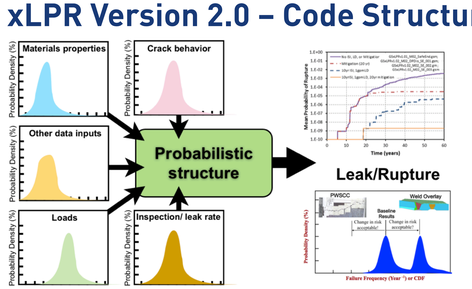
Objectives of Research Sponsored by the NRC and the Electric Power Research Institute (EPRI)

- Develop a robust methodology for evaluating reactor coolant system piping rupture probabilities.
- Select appropriate, technically sound input data and models to produce best-estimate output results with quantified uncertainty.
- Develop a computational software tool that applies the input data and models and appropriately treats epistemic and aleatory uncertainties.
- Verify, validate, benchmark, and document the software tool to enable its use in support of design and regulatory decisions by both industry and the NRC.

Cooperative Research

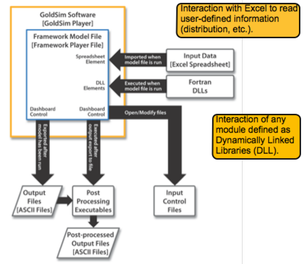
- An NRC/EPRI memorandum of understanding (MOU) was signed to allow and encourage cooperation in nuclear safety research that provides benefit for both the NRC and industry.
- The MOU is authorized under Section 31 of the Atomic Energy Act and Section 205 of the Energy Reorganization Act.
- The xLPR project is being conducted under an addendum to the MOU to allow the NRC and EPRI to cooperatively conduct research on this project.

xLPR Version 2.0 – Code Structure

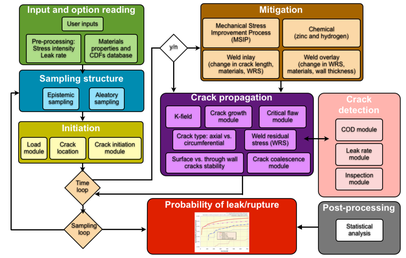


Probabilistic Fracture Mechanics Concept

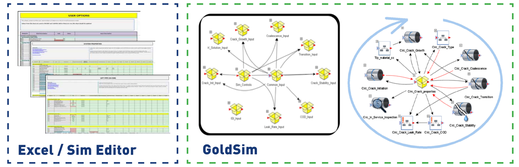
Object oriented to allow development of algorithms via graphical elements with specific properties (dashboard).



GoldSim Structure



xLPR Version 2.0 Module Structure



User interface

Defined by the input group and Excel spreadsheets hosting distributions for input parameters.

Landing platform

Definition of all input variables as well as simulation controls.In collaboration with the input group (simulation settings) and the model group (input/ output of each model).

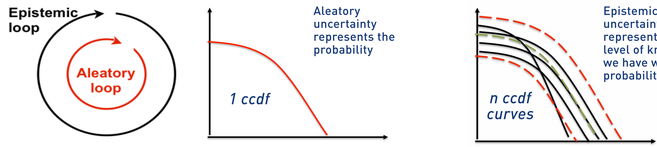
Physical (deterministic) models

Definition of all input variables as well as simulation controls.Each container host module developed by the model group and compiled as a DLL.

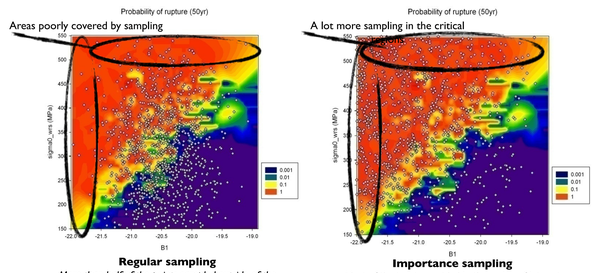
xLPR Version 2.0 Framework Structure

xLPR Version 2.0 – Uncertainty Treatment

- Uncertainty is treated as either aleatory (inherent randomness) or epistemic (lack of knowledge).
- Uncertainty is propagated through a double nested loop structure—aleatory represents the probability, epistemic represents the uncertainty in this probability.



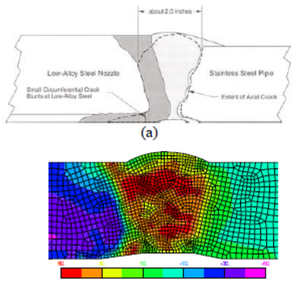
- Uncertainty is sampled using a variety of sampling scheme, e.g., random sampling, Latin Hyper Cube Sampling, and Discrete Probability Distributions with the option to importance sample.



Regular sampling
More than half of the points sampled outside of the region of interest

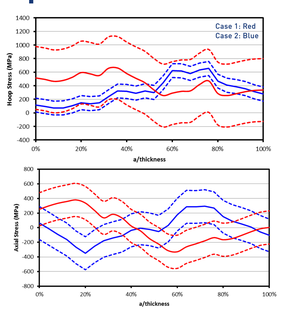
Importance sampling
Most of the points sampled in the region of interest

xLPR Version 2.0 – Sample Results

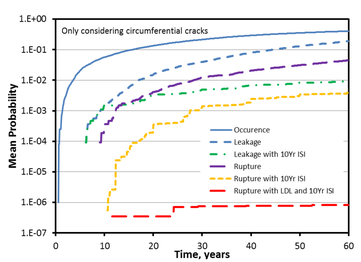


Problem Geometry

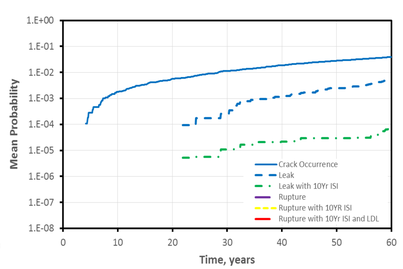
Note: xLPR version used not verified



Problem Weld Residual Stress



Case 1—considering circumferential cracks only



Case 2 – considering axial and circumferential cracks

xLPR Version 2.0 – Schedule

- xLPR Version 2.0 beta released – December 16, 2014.
- Verification and validation effort ongoing and scheduled to be complete in May 2015.
- xLPR Version 2.0 planned release – Summer 2015.
- xLPR final reporting – December 2015.